To Be Determined September 15, 1987

Borgwaldt Cylinder Volume Test (USA)

Primary Methodology Committee

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A. Objective and Applicability

1. The objective of the Borgwaldt Cylinder Volume (CV) Test is to measure the volume of given weight tobacco filler using an instrument designed by the Heinr. Borgwaldt Company. The results of the test are expressed in cubic centimeters per gram.

2. The person performing this test must have been trained in the past 12 months in accordance with the following which are available from the Employee and Environment Protection Department:

   a. Job Procedure 45-07, "Q.A. Chemical Sampling Equipment, Balances"

   b. Job Procedure 46-03, "Q.A. Physical Test Equipment, Borgwaldt Volume Tester."

3. Parts of this procedure are limited to those facilities which use PMUSA equilibration standards of 75°F and 60% relative humidity (RH) and the PMUSA OV test conditions of 100°C for three hours..

4. The standard error of the estimate is approximately 1.4%. (Derived from data in Reference 9.)

B. Definitions

1. Borgwaldt CV Instrument - A device designed by Heinr. Borgwaldt Company which measures the cylinder volume of tobacco filler. See Figure I.

2. Borgwaldt Volume (BV) - A term frequently used to mean a cylinder volume determined on a Borgwaldt instrument.

3. Cylinder Volume (CV) - The volume that a given weight of tobacco at a given OV occupies under a given pressure, cc/g.

4. Corrected Cylinder Volume (CCV) - Within certain limitations, the expected cylinder volume at an arbitrarily selected OV value, cc/g. It is computed by "correcting" the measured CV for the OV of the tobacco. (See Section H -- Technical Information.)

5. Equilibrium Moisture Content - The amount of moisture tobacco will hold at 60% relative humidity (RH) and 75°F.

6. Equilibrium Oven Volatiles - The oven volatiles as determined after the tobacco has reached its equilibrium moisture content.

7. Oven Volatiles (OV) - Those volatiles in tobacco that are evolved by treatment in a forced draft oven at 100°C for 3 hours, weight % (see PPI 440-204).

8. Equilibration - A process of subjecting tobacco to an air stream of fixed temperature and humidity for the purpose of bringing the moisture in the tobacco into equilibrium with the moisture in the air

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(i.e., moisture will be absorbed and released by the tobacco at equal rates). This process is designed to bring different samples of similar tobacco types to approximately the same %OV so that any variation in test results caused by different OVs are minimized or eliminated.

9. Sampling scoop - a device designed by Philip Morris for the purpose of obtaining samples from locations that are not easily accessible. (See Section C.10.)

C. Apparatus

1. Borgwaldt CV instrument, Densimeter Model #DD-60, Heinr. Borgwaldt Company, Friese Weg4 2000 Hamburg 50 West Germany. (In the model number, the "DD" specifies models which use digital display readout while "DM" specifies analog readout; and "60" specifies a 60mm measuring range, a "30" specifies a 30mm measuring range, etc.)

2. Guard, plastic, fabricated in accordance with Philip Morris R&D Development Engineering Drawing Number 1814-092A. (See Figure II.)

3. Plastic cup, 250 ml, Gilbert Plastics, Inc., Somerset, NJ (or equivalent) (General Scientific).

4. Electronic top loading balance, 300 grams capacity, 0.001 gram resolution (Mettler PK-300 or equivalent).

5. Calibration weight, 100 gram (General Scientific - #4-3540-10).

6. Extra wide-mouth funnel, polyethylene, two inch diameter mouth (Model 78110, United States Plastic Corp. 1376 Neubrecht, Lima, Ohio 45801).

7. Sample dishes for oven volatiles determination, see PPI 440-204.

8. Plastic cleaning rod or brush.

9. Sampling scoop, double-sided, fabricated in accordance with Philip Morris Engineering Drawing Number D-133517 (available from Philip Morris USA Engineering — Documents Group).

10. Sample containers, rigid, polyethylene, 8¼ x 6 x 3¼ inches, Bel Art #H16741 (General Scientific).

11. OPTIONAL EQUIPMENT: HP-97 Calculator or equivalent with program card.

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D. Sample Collection

1. Obtaining Sample

a. The person obtaining the samples must be trained in accordance with the facility's Job Procedure for sampling at a each sampling location. The person must use all appropriate safety equipment and procedures called for in the Job Procedure.

b. With the exception of filler from ripped cigarettes, samples for CVs are to be collected from a free falling stream of tobacco into a rigid container which is then sealed for transportation. Filler from ripped cigarettes must also be inserted in rigid containers and sealed.

c. The sample scoop is not required to collect the sample if the sampling point is easily accessible. Consult with the supervisor or facility safety personnel to determine the need for the sampling scoop.

d. When obtaining a sample in the factory, the sampling scoop or other rigid sample container is placed in the falling tobacco stream and moved quickly from side-to-side to obtain tobacco from all parts of the stream. When using the scoop, collect the sample in the small scoop side.

e. When the scoop is full, the contents of the scoop are transferred to a sample container by placing the container on top of the scoop, inverting the scoop and container, and then gently lifting the scoop away from the container. This method is used to minimize any degradation of the sample.

f. Secure the lid on sample container.

2. A full scoop or sample container will provide adequate sample weight for the CV test. The total weight collected is estimated to be 150 ± 30 grams for all samples except expanded tobacco, ES and ESB; 100 ± 30 grams for expanded tobacco, ES, and ESB samples.

3. The minimum sample weights needed for the CV test are given in Section F.5. Add 20 grams to these weights for the oven volatiles test.

E. Calibration

1. Borgwaldt CV Instrument (See also Figures I and II.)

a. The instrument must be calibrated before it is used after initial power-on and every four hours of continuous operation thereafter regardless of the number of samples tested during that period.

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b. Inspect the power cords and interconnecting cables on the Borgwaldt unit and the Digital Display Unit for frayed, damaged, or broken wires and plugs. Have any defective wires and plugs repaired or replaced by qualified personnel.

Check the power supply against the name plate on the Borgwaldt unit. If there is any doubt about the power supply, wiring, or plugs, contact the facility electrician for assistance.

c. ENSURE THE UNIT IS EQUIPPED WITH THE PLASTIC GUARD DESIGNED BY PHILIP MORRIS (See Figure III) OR THE EQUIVALENT GUARD DESIGNED BY BORGWALDT (1987 and later models). DO NOT OPERATE THE UNIT WITHOUT ONE OF THESE GUARDS IN PLACE.

d. Borgwaldt normally supplies an additional one kilogram weight (Part Number D38.0123.00) with each unit. This weight is not used in Philip Morris' CV measurement.

e. Turn the unit on by placing the on-off switch (marked "Ein/Aus") in the "Ein" position. Also turn on the power to the digital display unit by placing the "O I" switch in the "I" position. The switch is located on the front of the display for the older style units and on the back of the display for the newer style units. (See Figure II) Allow the unit to warm up for 30 minutes before calibrating or using.

f. Place the changeover switch (marked "Cigarettes/Tobacco") in the "Tobacco" position. (The "Tobacco" position is used for cylinder volume while the "Cigarette" Position is used for firmness with a different holder. This firmness test is not recommended for use within PMUSA at this time.)

g. Check that the probe magnet is secured to the metal plate at the top of the Borgwaldt housing. If not, no change in the digital readout display will occur. Repair/replace as necessary.

h. Remove the cylinder from beneath the piston; and using a brush, clean all tobacco particles from the underside of the measuring head on the piston and from inside the Borgwaldt cylinder.

i. Place the empty cylinder in position underneath the piston. Ensure the groved bottom on the cylinder fits into the rail on the test unit and that the back of the cylinder is pushed completely back against the front of the test unit.

j. For the older style digital display units (pre-1987) as shown in Figure II-A:

(1) Place the direction switch (marked "Richtung") in the left position. (The "Richtung" switch determines the starting point from which a height is measured.)

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(2) Using the thumbwheel switches located to the right of LED display, set the preselection counter to 00000.

(3) Set the Thumbwheel switch marked "+" or "–" to the "+" position.

(4) The thumbwheel switches calibrate the internal electronics for height and direction from the starting point.

(5) Set the timer on "1" (10 seconds).

(6) Press the "Start" switch on the tester.

(7) When the measuring head has reached its lowest position and the timer is counting, press the "delta" button (marked with a small triangle). The lowest position is reached when the instrument makes a slight clicking sound.

At the same time observe the shaft on the height sensor to the left of the main piston. Some part of the shaft must be visible between the head on the top of the shaft and the rubber "O" ring resting on top of the sensing unit. If no part of the shaft is visible, the main piston travel may have been stopped by the sensing head rather than the bottom of the tobacco cup! To correct this condition, shorten the height of the magnet by approximately 1 mm; then, repeat step (7).

k. For the newer style digital display unit (post-1987) as shown in Figure II-B:

(1) If the display shows a blinking "0.000", depress the [REF] key twice.

(2) Check the seven programming options for the display unit. Each option is initiated by simultaneously depressing the keys indicated in the "Call-Up Sequence" below. Then observe the values shown on the digital display.

Call-Up Sequence	Display Response	Meaning
[CE][Ø]	PØ Ø*	RS232 interface control.
[CE][1]	P1 1	Direction of measurement (1 means upgoing is positive).
[CE][2]	P2 Ø	Zero means metric measurement.
[CE][3]	P3 1	One means 1/1000 mm resolution.
[CE][4]	P4 Ø	Zero means conversion factor is one

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[CE][5]	P5 Ø	Zero means [CE] is parameter call only.
[CE][6]	P6 5*	RS232 interface control.
[CE][7]	P7 6	Display hold/free running by external control (the CV tester).
	P7 1*	Display minimum value (may be needed for some computer hookups).

* The proper setting for these program options will depend on the RS232 interface and the computer program needs. If a computer is used to read the display, consult with the appropriate computer personnel to determine the correct settings.

(3) If any of the underlined values in (2) above do not appear on the display as indicated, enter the appropriate value from the numeric keypad on the front of the display.

(4) Press the [ENT] key to end each of the program check options.

(5) Set the timer on "1" (10 seconds).

(6) Press the start button on the tester.

(7) When the measuring head has reached its lowest position and the timer is counting, press the [Ø] key followed by the [ENT] key to zero the display. The lowest position is reached when the instrument makes a slight clicking sound.

At the same time observe the shaft on the height sensor to the left of the main piston. Some part of the shaft must be visible between the head on the top of the shaft and the rubber "O" ring resting on top of the sensing unit. If no part of the shaft is visible, the main piston travel may have been stopped by the sensing head rather than the bottom of the tobacco cup! To correct this condition, shorten the height of the magnet by approximately 1 mm; then, repeat step (7).

l. After the measuring head has retracted, press the start button again. The measuring head will again descend to the bottom of the tobacco cup. After the measuring head retracts, read the height of the calibration disc on the LED display.

m. If the displayed height is between -0.005mm and +0.005, the unit is considered to be calibrated.

If the displayed height is not within tolerance, repeat steps 1.j.(7) or 1.k.(7) as appropriate. If the unit fails to calibrate after five tries, contact the supervisor or instrument technician.

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2. Top Loading Balance

a. Balance accuracy is to be confirmed at the beginning of each shift using a clean, calibrated "working" standard weight. The working standard weight located in the lab is to have documentation of the last and next calibration dates and the value of the weight at its last calibration.

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b. Inspect the power cord on the balance for frayed or damaged wires and broken plugs. Have any defective wires or plugs replaced or repaired as necessary by appropriate personnel.

Check the power supply requirements against the name plate on the balance. If there is any doubt about the power supply, plugs, or wiring, contact the facility electrician for assistance.

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c. Check the calibration and operation of the balance as follows:

(1) Level the balance.

(2) Clear the weighing area of any foreign material that may interfere with the weighing mechanisms.

(3) Connect the power cord to the power supply, turn on the power to the balance and depress the tare button. (For Mettler balances, both steps are accomplished by depressing the control bar down as far as it will go. Other manufacturers' balances may require a different procedure; consult the manufacturer's operating manual for exact details.)

(4) When the "0.000" appears in the weight window, place the 50 gram working standard weight on the balance pan.

(5) After a few seconds, the final weight will appear on the display when the third digit of the display stabilizes. Record this value on a calibration worksheet or log book.

(6) Remove the 50 gram weight and place the 100 gram weight on the balance. After the balance display stabilizes, record the displayed value on the calibration worksheet or log book.

(7) Each of the weights is to be within 0.002 grams of the known weight of the working standards.

(8) If an initial "0.000" or the correct weights cannot be obtained, notify Lab Supervisor.

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3. Monitor Check

a. Following the calibrations in E.1 and E.2. above, two monitor CV samples are to be tested at the beginning of each day in the same manner as regular samples. Follow the directions in Section F below for the testing procedure.

b. The monitors are to be of similiar composition as that of the majority of the samples tested. Thus, use ET monitors if samples of ET are being tested; cigarette filler, if ripped cigarette filler is being tested, etc.

c. For each monitor CV sample, two OV samples are required (see PPI 440-204).

d. Monitor sample results are to be calculated for CV, OV, and CCV in the same manner as regular samples. Follow the directions in Section G below for calculating results.

e. $\bar{X}$ and R charts are to be plotted for CV, OV, and CCV to determine if the instrument is in statiscal control. (Refer to statistical textbooks/handbooks for assistance in constructing and evaluating control charts; e.g., references 14 and 15.)

F. Testing Procedure

1. Obtain samples in accordance with Section D.

2. Samples may be tested either "as-is" or equilibrated. If corrected cylinder volumes are to calculated, samples must be equilibrated. Transfer the samples for equilibration to the equilibration facility and follow the procedure for equilibrating tobacco samples.

3. Calibrate instrument in accordance with Section E.

4. Place the clean, plastic cup on the balance and depress the "tare" button. Remove the cup when the balance indicates "0.000" on its weight display.

5. Weigh out the appropriate amount of the sample into the plastic cup. Weighing and anlysis must be done quickly to avoid any significant change in equilibration OV due to exposing the sample to ambient conditions. The total elapsed analysis time from initial weighing until the final reading is displayed on the instrument is not to exceed two minutes. This time consideration may be ignored if the entire analysis process takes place in a laboratory where temperature and humidity are controlled to 75°F and 60% relative humidity.

a. Turn the sample container upside-down and gently shake the sample to mix back into the sample any small particles that may have settled to the bottom of the container.

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b. Open the sample container and remove some of the sample.

(1) If the sample is composed of small, untangled pieces of tobacco, a small laboratory scoop or spoon is to be used to remove the tobacco.

(2) For long-strand, tangled tobacco, gentle pinch a portion of the sample between the fingers and remove from the sample. Do not shake the portion in the fingers as this will cause mainly the small pieces to drop out and, thus, bias the test results. Every effort is to be made to obtain a representative portion of the sample

c. Keep the sample container closed except when removing parts of the sample.

d. For locations using computer/calculator pre-programmed sample weights,

(1) the sample weight for all samples except ET, ES, and ESB is to be 20 ± 0.002 grams.

(2) the sample weight for ET, ES, and ESB is to be 10 ± 0.002 grams.

e. In the absence of pre-programmed sample weights,

(1) the sample weight for all samples except ET, ES, and ESB is to be 20 ± 2 grams.

(2) the sample weight for ET, ES, and ESB is to be 10 ± 1 grams.

6. Record the sample weight on the appropriate column on a CV worksheet. (Sample worksheet shown in Appendix I)

7. Place the wide-mouth funnel into the top of the Borgwaldt cylinder and gradually pour the sample from the cup into the cylinder.

8. Shake the cylinder gently in a horizontal direction to provide a flat surface on the top of the tobacco column within the cylinder.

9. Position the cylinder under the measuring head.

10. Set the timer on "3" (30 seconds) and press the start button.

11. At the end of the test period, the measuring head will retract, and the height of the column of tobacco will be shown on the LED display to the nearest 0.001 mm.

12. Record the height of the compressed tobacco column as shown on the LED display on the CV worksheet.

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13. Weigh out sufficient tobacco from the cylinder for an OV determination (two dished) in accordance with PPI 440-204.

14. Dispose of any excess tobacco in the cylinder in accordance with the facility's operating procedures and clean the cylinder with the plastic cleaning rod.

15. Dispose of the tobacco in the sample container in accordance with the facility's operating procedures.

16. Repeat steps 3-15 for the remaining samples.

17. Calculate the results as described in Section G and record on the CV worksheet in the appropriate columns.

18. Calculate OV results (see PPI 440-204) and record on the CV worksheet in the appropriate columns.

G. Calculations

1. Cylinder Volume -- Manual Method

a. The basic formula for the cylinder volume is:

$$C.V. = \frac{\text{Volume of the Cylinder}}{\text{Sample Weight}}$$

where: Sample weight = 20gm for regular filler
= 10gm for expanded filler

Volume of the cylinder, in cubic centimeters (cc), is given by the formula

$$\text{Volume} = (pi)(r^2)(h) = \frac{(pi)(D^2)(h)}{4} \qquad \text{[Equation 1.a]}$$

where pi = the constant, 3.1416
r = radius of cylinder, cm
D = diameter of cylinder, cm
h = height of cylinder, cm

b. Then, the expanded formula for cylinder volume is

$$C.V. = \frac{(pi)(D^2)(h)}{(4)(\text{Sample Weight})} \qquad \text{[Equation 1.b]}$$

c. The height of the cylinder in Equations 1.a and 1.b is the height of the compressed tobacco column as shown on the digital display. Since this height is displayed in millimeters and the "h" in Equation 1.b is in units of centimeters, an additional conversion factor must be applied:

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$$C.V. = \frac{(pi)(D^2)(h'/10)}{(4)(\text{Sample Weight})}$$ [Equation 1.c]

where h' is the height, in millimeters, of the compressed tobacco column as shown on the LED display in the Borgwaldt CV test.

d. Since the diameter of any given cylinder is a constant, the only two variables in the above equation are h' and Sample Weight. These were the two values determined in the CV test. Therefore, equation 1.c is frequently reduced to a "working" equation with the constant terms and diameter of the cylinder incorporated into one constant.

For example, assuming a cylinder with a diameter of 6.00 cm, equation 1.c. would reduce to the following "working" equation:

$$C.V. = \frac{(2.8274)(h')}{\text{Sample Weight}}$$ [Equation 1.d]

e. Examples using the "working" equation 1.d

(1) If the height displayed on the Borgwaldt unit for a regular tobacco sample of 20 grams was 32.555mm, then

$$CV, cc/g = \frac{(2.8274)(32.555)}{20}$$

$$CV, cc/g = 4.60$$

(2) If the same height, 32.555, was for an expanded tobacco sample of 10 grams, the CV would be

$$CV, cc/g = \frac{(2.8274)(32.555)}{10}$$

$$CV, cc/g = 9.20$$

2. If pre-programmed calculators or computers are used, it is imperative that the supervisor verify the correctness of the equations prior to use. Frequently, these programs use a constant factor in the "working" Equation 1.d that incorporates all the necessary conversion factors, the cylinder diameter, and, sometimes, the target sample weight. While the constant factor is technically valid only for cylinders with the same diameters, cylinders with diameters within ±0.01 of each other may use a common factor. The error so introduced is insignificant. Following is a table listing the constant term in the equation for various cylinder diameters.

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Cylinder Diameter, cm	Constant for Equation 1.d	Constant with a Sample Size of 10 grams	Constant with a Sample Size of 20 grams
5.94	2.7712	0.2771	0.1386
5.95	2.7805	0.2781	0.1390
5.96	2.7899	0.2790	0.1395
5.97	2.7992	0.2799	0.1400
5.98	2.8086	0.2809	0.1404
5.99	2.8180	0.2818	0.1409
6.00	2.8274	0.2827	0.1414
6.01	2.8369	0.2837	0.1418
6.02	2.8463	0.2846	0.1423
6.03	2.8558	0.2856	0.1428
6.04	2.8653	0.2865	0.1433
6.05	2.8748	0.2875	0.1437
6.06	2.8843	0.2884	0.1442

3. If a computer or pre-programmed calculator card is used to make the CV calculations, follow the facility specific instructions for use of that equipment. The user must always beware of any calculated CCV generated by a computer/calculator program card as they frequently use an older, invalid calculation technique. Replace the computer or calculator result, if necessary, by the results obtained in Section G.4.

   The instructions on the use of the original CV-OV-CCV HP97 calculator program card are given in Appendix II.

4. Correcting CV Samples

   a. Variation in tobacco OV has a significant effect on CV. As a result, there has always been interest in "correcting" CV results to a predetermined OV basis so that observed variation in product CV can be brought to a common basis for comparative analysis. The Corrected Cylinder Volume formula is as follows:

$$CCV = CV_{eq} + (CF)(OV_{eq} - OV_{target})$$

   where:
   - CV_{eq} = CV of equilibrated tobacco sample as calculated above.
   - CF = correction factor from Appendix III.
   - OV_{eq} = OV of equilibrated tobacco sample used for CV test.
   - OV_{target} = predetermined target OV from Appendix III.

   Note that the correction equation is valid only for CV results obtained on equilibrated samples. The equations and correction factors cannot be used on "as-is" samples.

   b. It has also been observed, however, that simple, straight-line correction factors (such as the one in the equation above) are

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valid only for a particular blend and only over a narrow range of OV. A CV of a sample whose equilibrium OV is outside the maximum acceptable OV range cannot be corrected without the danger of introducing significant errors. Correction factors, "target" OVs, and maximum acceptable OV ranges for various blend components through PMUSA Primaries are given in Appendix III.

c. Examples (using data from Appendix III for MKS blend):

Sample Location	CV_{eq}	OV_{eq}	CCV
Exit Cutters	4.6	13.5	4.6+(.35)(13.5-13.75) = 4.51
Exit Cutters	4.6	16.0	NA (OV_{eq} outside 13.75±1.00)

H. Technical Information

1. The information contained in the following paragraphs has been generalized from one or more of the sources listed in Section I. The reader is encouraged to review the original source literature for a more thorough understanding of the material.

2. During the initial evaluation of the Borgwaldt CV instrument (Ref. 9), the 95% confidence interval for the Borgwaldt test was determined to be:

$$95\%\ \text{Confidence Interval} = \text{Mean} \pm \frac{0.0276}{n^{\frac{1}{2}}}\ (\text{Mean})$$

where n is the number of samples averaged together to obtain the mean.

3. The Borgwaldt CV instrument was also found to be relatively insensitive to sample weight. Cut filler samples with weights ranging from 15 to 27 grams all yielded results which were not statistically different. The very tight weight tolerance used by most QA applications is due to the fact that a fixed sample weight is built into the constants stored in the calculator/computer programs.

4. When the Borgwaldt unit was first adopted, it was recognized that each of the cylinders may be a different diameter. A proposal was made to use a constant diameter of 6.00 cm. The maximum error was expected to be only about 1% (Ref. 4). This estimate was based on the maximum expected variation between the actual and nominal diameter (thought to be ±0.03 cm from the nominal). This error was accepted in order to allow interchanging cylinders without requiring the entry of the specific diameter (potential data entry errors) or updating computer programs. This constant for a cylinder diameter of 6.00 cm, 2.8274, was programmed into many programmable calculators and computer programs. It was later shown (Ref 16) that the use of this single cylinder diameter increased variation between Borgwaldt units, and in some cases caused two Borgwaldt units to appear to be yielding

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statistically different results. Therefore, the practice of using a constant diameter is no longer being followed.

Relatively small differences in diameter (±0.01 mm) do not cause any significant errors. Therefore, laboratories with multiple units can use a constant diameter if all sample cups are within ±0.01 mm of each other. For multiple units, calculate the average diameter of all the cups in use and round-off the result to the nearest 0.01 mm. The constant term for the average diameter can be found in the table in Section G.2.

5. Because the measured cylinder volume (CV) of tobacco is strongly affected by its oven volatiles (OV), there has been long standing interest in "correcting" CV data to a constant OV basis so results could be compared "easily." Similiarly, in order to keep things simple, there has been a desire to use a correction factor that is constant for all tobacco types, blends, and OVs. Such a factor, unfortunately, is not feasible. Research has shown three important concepts:

   a. the CV-OV relationship is curved in the form of an exponential decay. Thus, CV is more severely affected by OV at low OVs.

   b. the independent variable in the CV-OV relationship is not OV; but relative humidity (RH). Thus, the practice of equilibrating samples at constant RH has evolved over the years ("standard" conditions of 75°F and 60% RH).

   c. different tobacco types and blends equilibrate to different OVs at the same RH.

   The practice of "correcting" CV results to a constant OV has persisted; even though it is not proper to do so in some cases. CVs should only be corrected to the same OV if it is certain that the differences in OV are due solely to errors associated with RH of the air used for equilibration and/or OV measurement.

   Thus, the correction factors, OV targets, and OV ranges given in Appendix III are based on a number of assumptions:

   a. the tobacco is of the indicated blend as designed for United States manufacture,

   b. the samples were equilibrated at 75°F ± 0.5°F and 60% RH ± 1% RH,

   c. the "true" tobacco or blend equilibrium OV at 75°F and 60% RH is at, or very near, the listed "Target OV,"

   d. the blend does not change substantially from sample to sample.

   e. the factory processing does not appreciably alter the tobacco or blend RH-OV characteristics.

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If any of these assumptions are violated, the correction factors are invalid.

6. Prior to the date shown in Section J.2, the Borgwaldt units were calibrated with a plastic calibration disk (sometimes called a "hockey puck"). This disk was nominally 20.00 mm thick. The reason the calibration disk was used in the beginning was that Borgwaldt first manufactured the CV tester with a height sensor that had a range of only 30 mm. Since the tobacco height for a 20 gram sample was in the 38± mm range, the sensor was located at a point so that its zero was approximately 20 mm from the bottom of the tobacco cup. This then gave an effective measuring range from 20 to 50 mm, but also restricted the travel of the piston to the same range. In order to calibrate the unit, the calibration disk was needed since the piston could not travel to the bottom of an empty tobacco cup.

   Shortly after the first units were manufactured, Borgwaldt switched to a height sensor with a 60 mm range. This allowed placing the sensor in a position that would allow the piston to travel completely to the bottom of an empty tobacco cup. Borgwaldt discontinued use of the calibration disk — basing calibration on zero being the bottom of the empty tobacco cup, but Philip Morris continued to use the disk. As questions began to arise about agreement between CV test units, several calibration disks were measured. They ranged from 19.96 to 20.07. Since this variation was easily avoided, the calibration method was changed from the calibration disk being 20.000 mm to the bottom of the empty tobacco cup being 0.000 mm.

I. References

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2. Fox, D. R. and Mokarry, W. L., Special Report "Derivation and Use of CV-OV 'Correction Factors'," April 25, 1985 (R&D Accession Number: C85-00075)

3. Mokarry, W. L., Interoffice memo "Borgwaldt CV Guards," February 25, 1985 (R&D Accession Number: C85-00904)

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5. McCranie, W. D., Interoffice memo "Borgwaldt CV Evaluation," July 21, 1983.

6. Mokarry, W. L., Interoffice memo "Operation of Borgwaldt CV Testers," July 7, 1983 (R&D Accession Number: C83-08140)

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9. Mokarry, W. L., Interoffice memo "Borgwaldt CV Tester Evaluation," June 23, 1982 (R&D Accession Number: C82-04368)

10. Hartung, H. A. and LaRoy, B. C., Special Report "Moisture Effects in Expanded Tobacco and the Formula Cylinder Volume (FCV)," January 22, 1982 (R&D Accession Number: C82-00029)

11. Full, D. A., Interoffice Memo "FCV Program for HP-67/-97, Runnability on HP-41C," May 19, 1982 (R&D Accession Number: C82-03570)

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16. Kelton, D. J., Interoffice Memo "Borgwaldt CV Study," June 9, 1988.

J. Revision History

1. [09/15/87] — Orginal Procedure prepared by M. M. Mobrem and D. J. Kelton issued.

2. [date] — Revised to (1) eliminate the calibration disk (also called the "hockey puck") from the calibration process, (2) include calibration process for new style digital display unit, (3) change calculations to use actual cylinder diameter rather than nominal diameter, and (4) inserted updated correction factors and equations.

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FIGURE I

Borgwaldt CV Instrument, Model DD-60

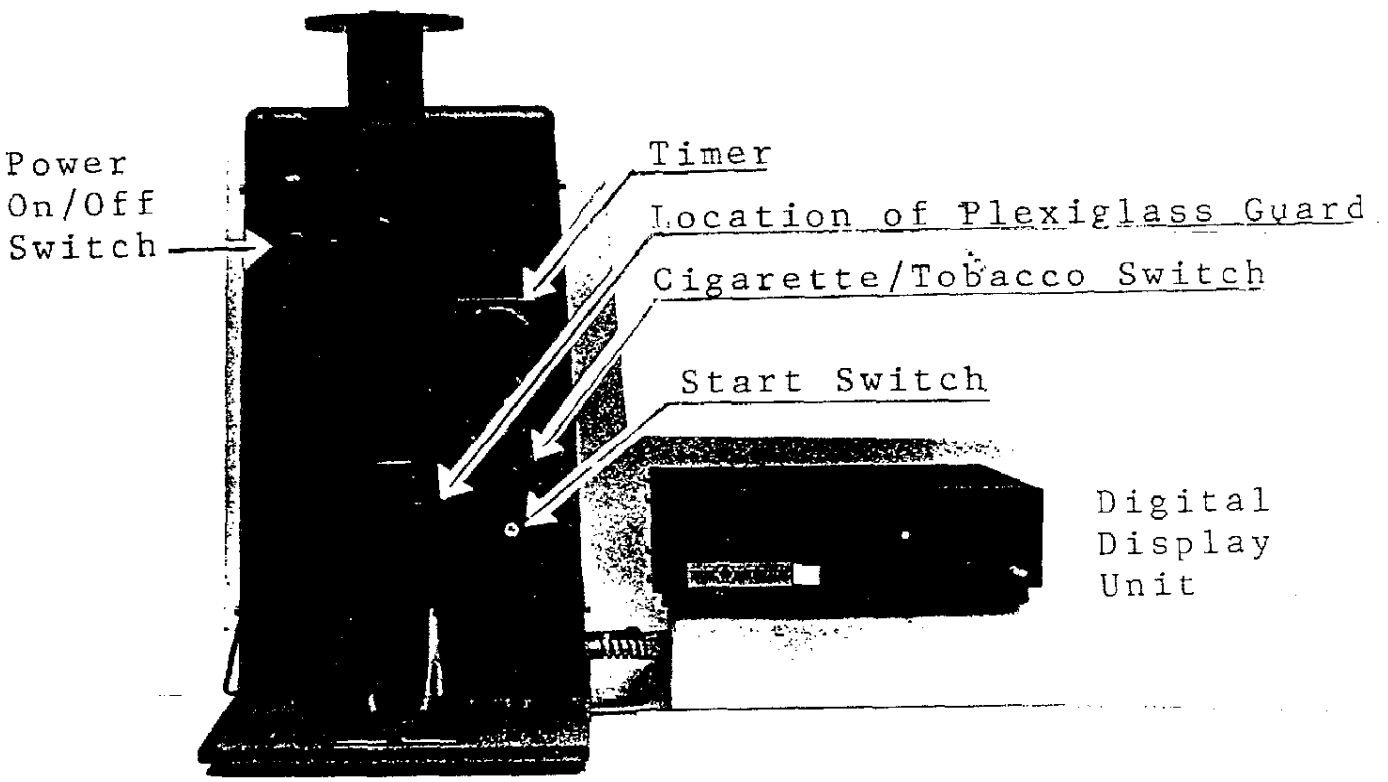

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FIGURE II

Digital Display Units, Borgwaldt CV Instrument

DIGITAL DISPLAY UNIT -- FRONT VIEW

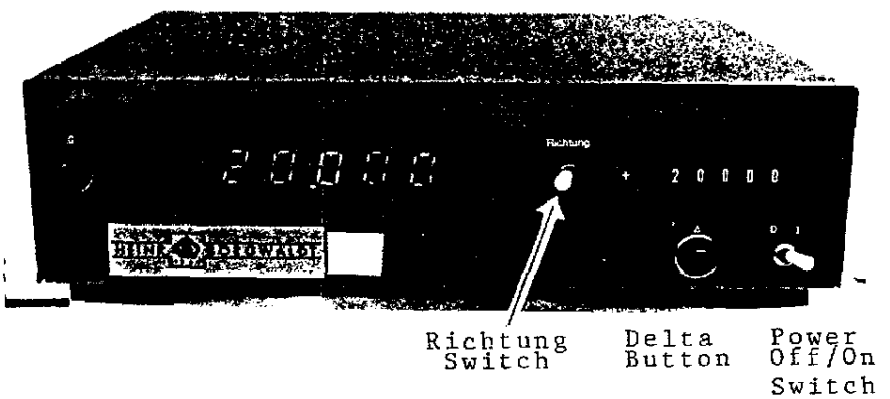

Figure II-A — Original Style Display Unit

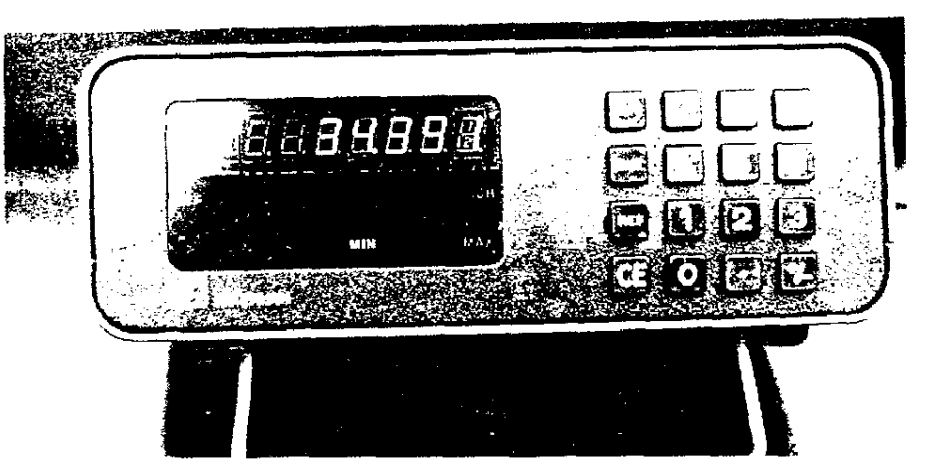

Figure II-B — New Style Display Unit

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FIGURE III

Guard, Borgwaldt CV Instrument

(R&D Development Engineering Drawing Number 1814-092A)

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APPENDIX I

BORGWALDT CYLINDER VOLUME

Technician: _____ Instrument Serial No.: _____

Date: __/__/__ Shift: _____ Cylinder Diameter: _____cm

Sample ID	Sample Weight, grams	Sample Height, mm	EQ-CV	OV Dish No.	OV Weights, grams			EQ. OV, %		CCV
					Tare	Wet	Dry	Each	Avg.	

APPENDIX II

Operation of HP-97 Calculator with CV-OV-CCV Program Card

1. Verify that the CV-OV-CCV HP97 program card has the correct constants for cylinder diameter and sample weights. Do not use a pre-programmed card unless the constants have been verified because some constants have been changed from those that were initially programmed on the card.

2. Calculate the CV as follows:

   a. load program into calculator
   b. press the "A" key
   c. key in the first height measurement
   d. press the "R/S" key
   e. key in the second height measurement
   f. press the "R/S" key
   g. key in the % OV
   h. Press the "R/S" key

3. The calculator will perform the necessary calculations and display the average height displacement, the Borgwaldt CV, and the Corrected Cylinder Volume (CCV) in the above order.

4. Do not use the CCV value displayed; it will be incorrect unless the orginal program card has been changed to reflect the new calculation technique. The correct CCV calculation is shown in Section G.4.

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APPENDIX III

Cylinder Volume Correction Factors

A. Assumptions

1. Tobacco has reached equilibrium OV with air at 75°F and 60% relative humidity (RH).

2. The "true" tobacco or blend equilibrium OV at 75°F and 60% RH is within one OV percent of the listed "Target OV,"

3. Tobacco blends do not change substantially from sample to sample.

4. Factory processing does not appreciably alter the tobacco or blend RH-OV characteristics.

B. The CV-OV correction factor and target OV for the Chesterfield NF family, the English Ovals family, the Merit Ultralight family, PM Lights, and PM Superlights are as follows:

1. Correction Factor (slope) = 0.37

2. Target OV, % = 13.00

3. Range of Actual Equilibrium OV that can be corrected using the above factor and target OV = 12.0 to 14.0 %OV.

C. The CV-OV correction factor and target OV for the Alpine family, the B&H family, the Cambridge family, Chesterfield 80, 85 and 100, the Eve family, the L&M family, the Lark family, the Marlboro family, the Merit Regular family, Multifilter 85, Paxton, the Parliament family, the Players family (except Navy Cut), the PM family except PM Lights and Superlights, Plus 120, PM Commander, the Saratoga family, the Virginia Slims family,

1. Correction Factor (slope) = 0.35

2. Target OV, % = 13.75

3. Range of Actual Equilibrium OV that can be corrected using the above factor and target OV = 12.75 to 14.75 %OV.

D. Any brand not listed in "B" or "C" above may not be corrected. Correction factors and target OVs have not been determined.

E. References

1. Kelton, D. J., Interoffice Memo "Borgwaldt CV Study," June 9, 1988.

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